Aura Validation Meeting, 21 – 23 September 2005

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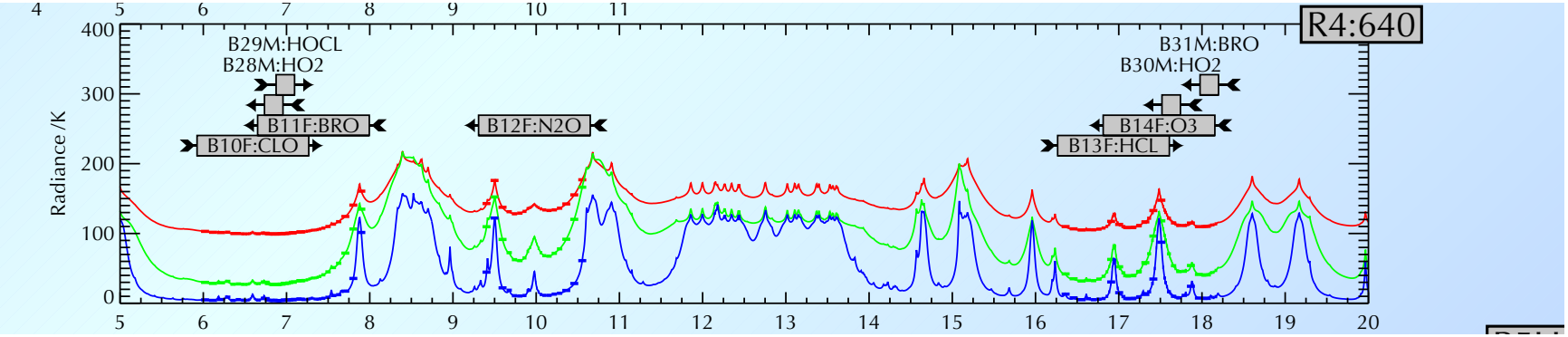
Overview of the EOS MLS N_2O product

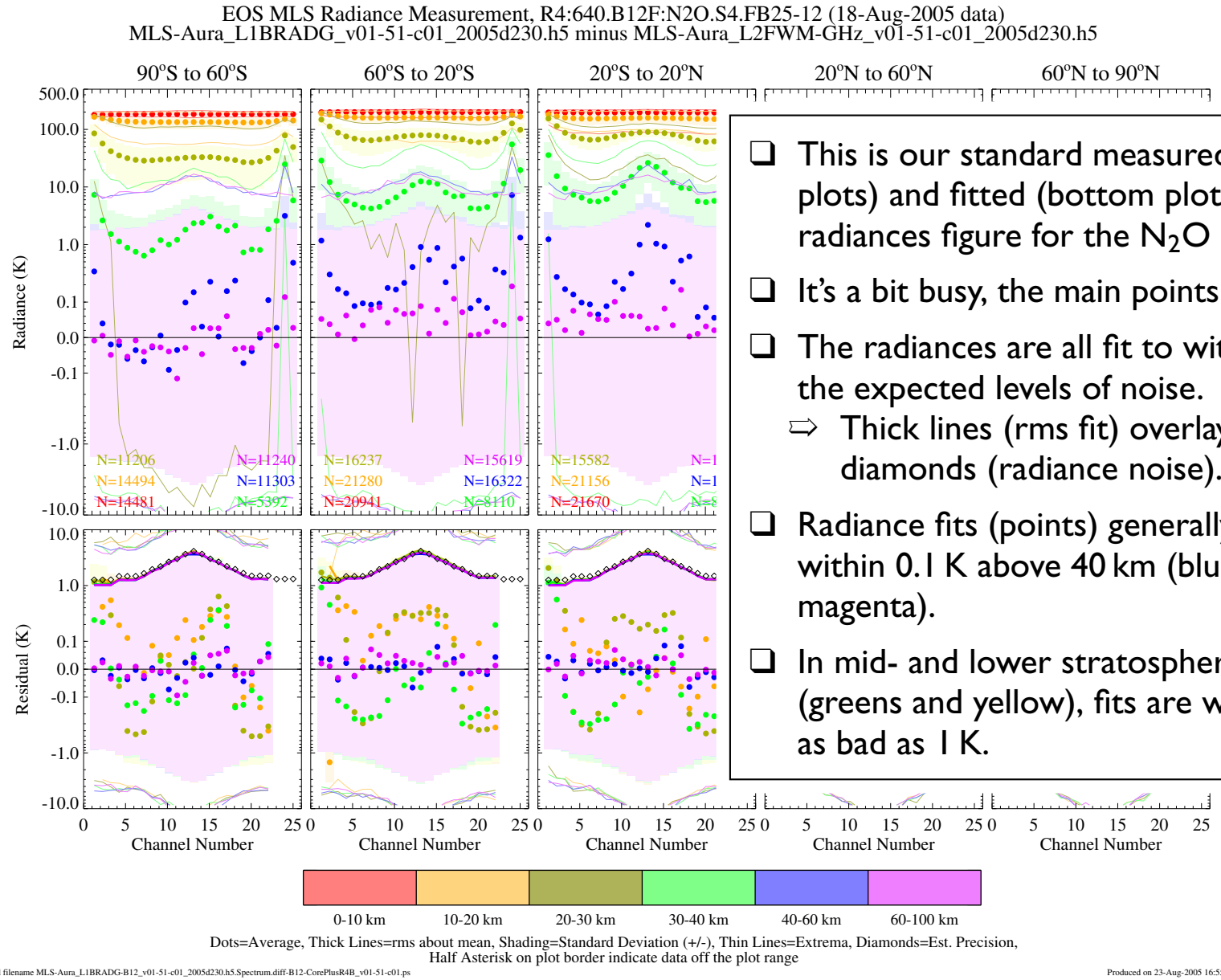
- This talk describes Nitrous Oxide (N_2O) data produced by version 1.51 of the EOS MLS data processing algorithms.
- These data are taken from observations of N_2O emission at 652.7 GHz.
- The v1.51 N_2O observations are useful between 100 and 0.1 hPa.
- Thick clouds in the upper troposphere have no discernible impact on the lower stratospheric observations.
- Profiles are retrieved on a grid with pressure as the vertical coordinate.
- N_2O abundances are reported at six pressure levels per decade change of pressure (~2.5 km).
  - ⇨ This coarsens to three per decade for pressures smaller than 0.1 hPa.
- The true vertical resolution of the N_2O is close to this in the mid stratosphere, but worse (~5 – 6 km) in the lowermost stratosphere and upper mesosphere.
- Horizontally, profiles are spaced by 1.5° great circle angle along the orbit track (~160 km, 24.6 s).

MLS N_2O radiances



- This plot shows typical observed radiances for MLS N_2O.
- The horizontal axis is 'intermediate frequency' in GHz.
- Spectra shown are for typical limb tangents at 100 hPa, 30 hPa, and 10 hPa.
- The N_2O line is the feature close to 10 GHz.
- The two strong features either side are emission from ozone.
  - ⇨ Uncertainty in the spectroscopy of these lines is a limitation on the v1.51 N_2O accuracy in the lower stratosphere.
- Other significant emitters in this region are nitric acid, various excited/isotopic ozone molecules and (in the upper troposphere / lower stratosphere) the water vapor continuum.

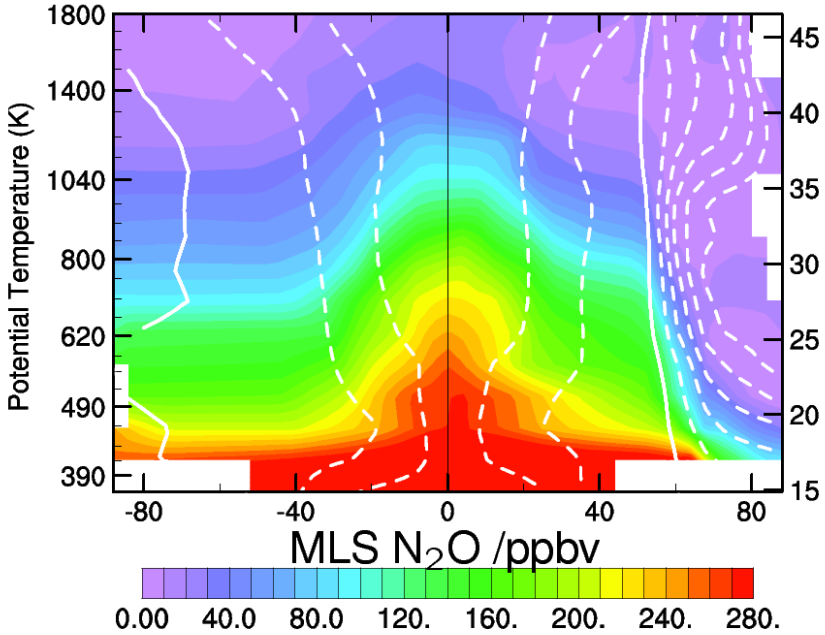
Typical radiance fits

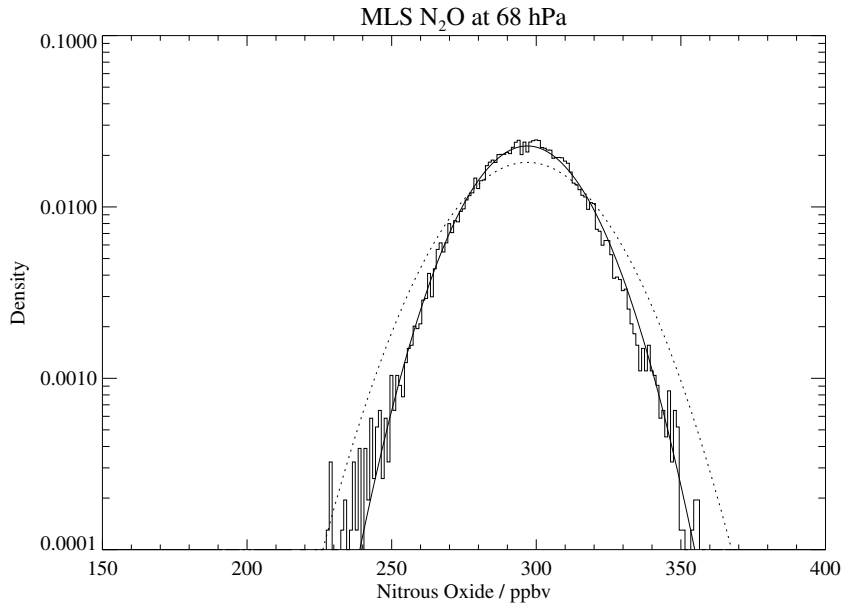


- This is our standard measured (top plots) and fitted (bottom plots) radiances figure for the N_2O band.
- It's a bit busy, the main points are:
- The radiances are all fit to within the expected levels of noise.
  - ⇨ Thick lines (rms fit) overlay diamonds (radiance noise).
- Radiance fits (points) generally within 0.1 K above 40 km (blue, magenta).
- In mid- and lower stratosphere (greens and yellow), fits are worse, as bad as 1 K.

Zero order validation – sanity checks

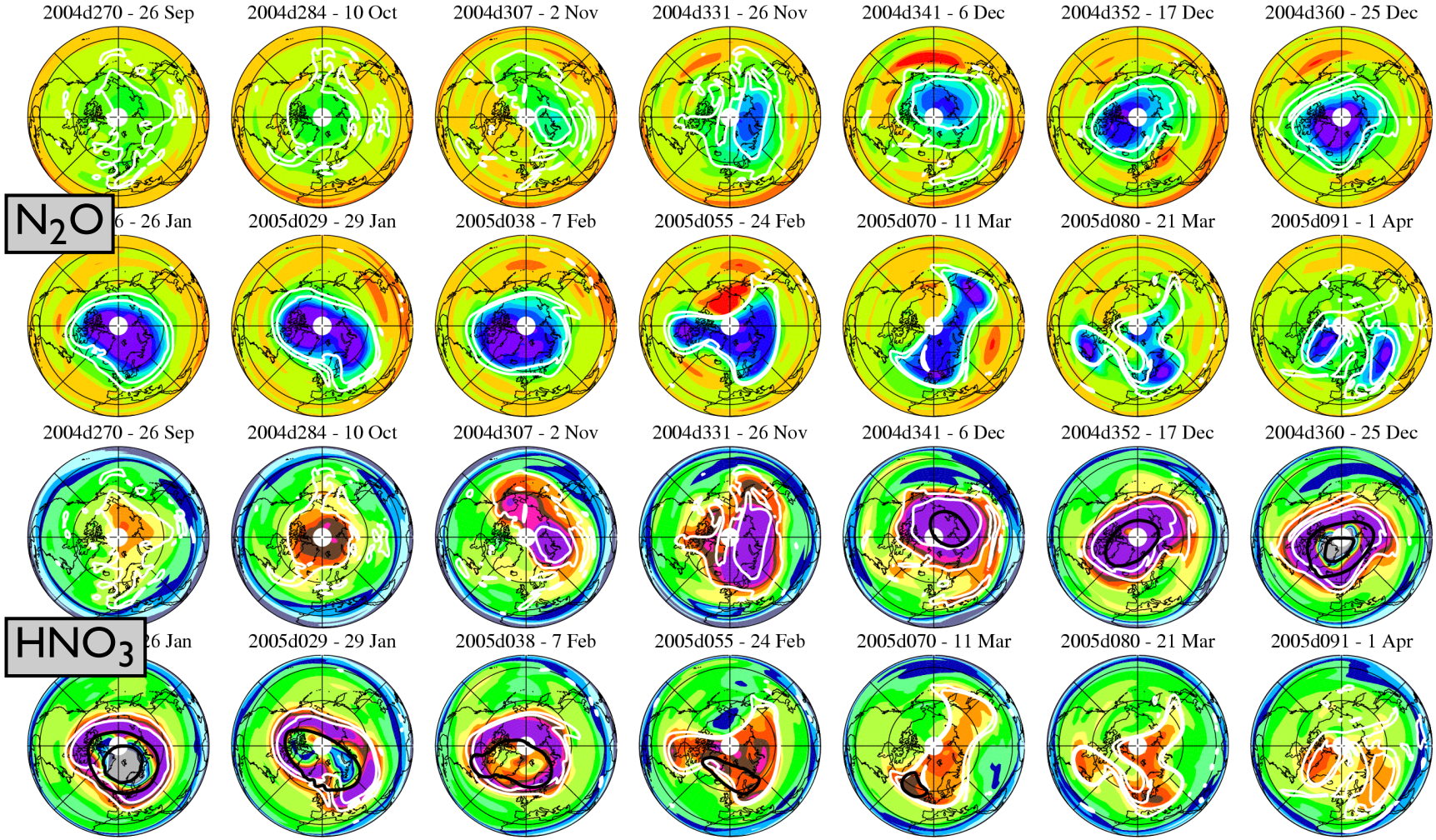
- The plot on the right is an equivalent latitude / theta mean of MLS N_2O for 28th January 2005 as a zero order 'sanity check'.
- This is part of one of our standard sets of plots of MLS data.
- The northern polar winter vortex is clearly well defined and the values look appropriate for N_2O.





- This histogram is all 68 hPa MLS N_2O for February 2005 between 20°S and 20°N.
- Variability should be low in this region.
- As expected, scatter in measurements is dominated by Gaussian radiance noise.
- Observed scatter is somewhat less than precision reported (dotted Gaussian).
- This is due to the nature of the smoothing constraints used.

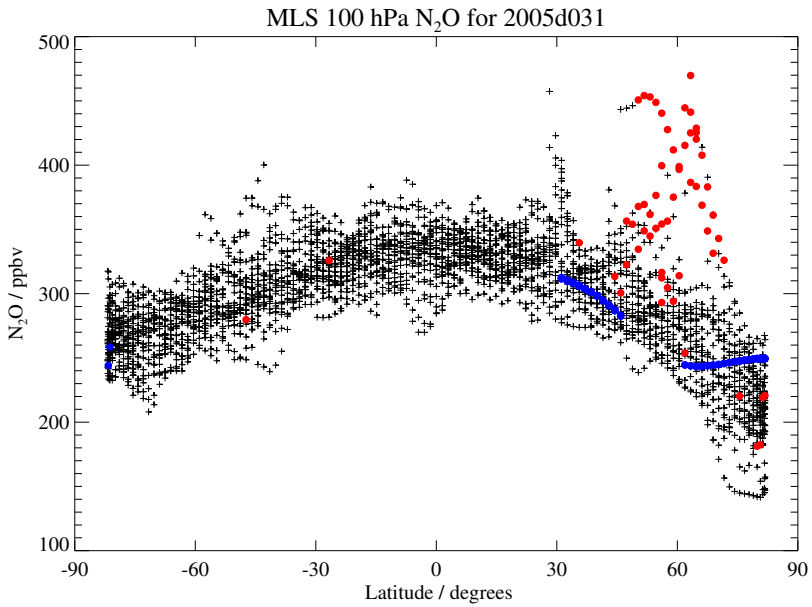
Comparisons with HNO_3 and GMAO P.V.



- The seasonal evolution of the northern polar vortex is well captured by MLS N_2O and agrees well with both the HNO_3 and the GMAO PV.
- The agreement around the time of the vortex break-up is particularly striking.

Anomalies in v01.51 N_2O

- This plot shows MLS N_2O at 100 hPa vs. latitude for 31st January 2005.
- The colored symbols illustrate anomalous N_2O retrievals.
- The red symbols indicate cases where the retrieval has converged to an inappropriate solution.

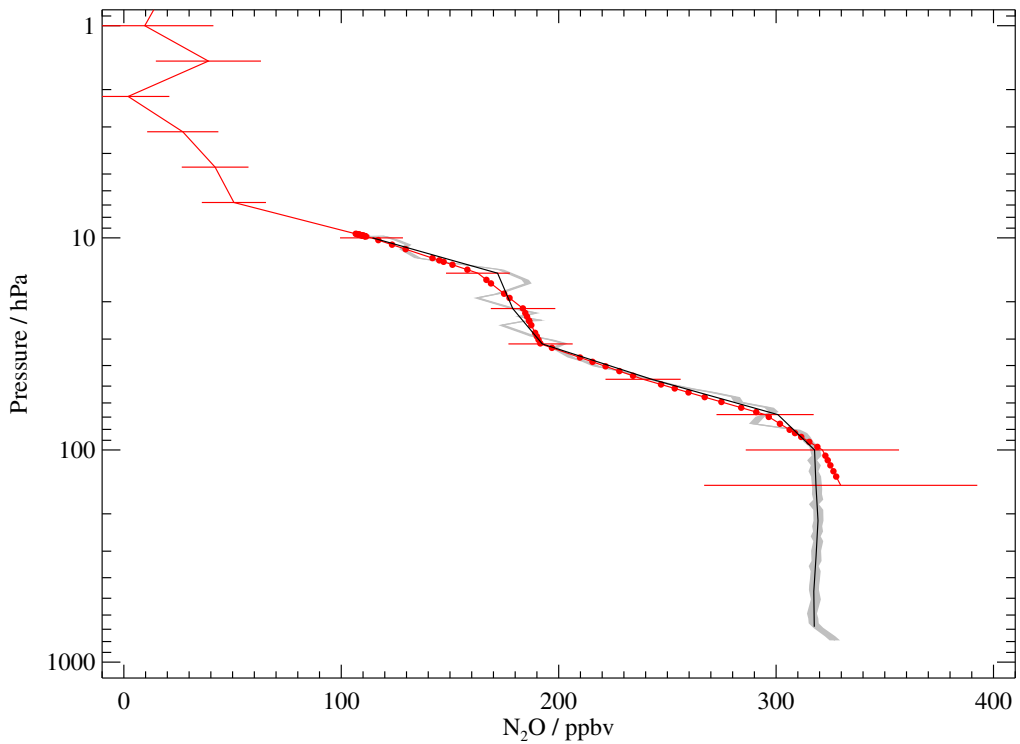


- These are flagged by an off-line algorithm, and the flags are available to users.
- This problem only affects data at 100 and 68 hPa.
- The blue points are cases where the retrieval has failed to converge to any useful solution.
- The values are left close to the *a priori* (smooth variations with time).
- Most of these are caught by applying the `quality` threshold detailed in the data quality document.

Discussion of comparisons shown

- While MLS measurements are fundamentally on pressure coordinates, most correlative measurements have height as their coordinate.
- MLS does retrieve geopotential height (based on the pressure/temperature retrieval and spacecraft pointing).
- This can be used to map between the MLS and correlative space.
- While some correlative sources include pressure as a product, I have opted for uniformity, to stick with this approach.
  - ⇨ It was not clear for some of the measurements how to relate the pressure and mixing ratio products.
- All these comparisons are unsophisticated 'closest coincidence' comparisons.
- My matching criteria are $\pm 1^\circ$ latitude, $\pm 8^\circ$ longitude and ± 12 hours.
  - ⇨ For the ASUR case it's $\pm 2^\circ$, $\pm 4^\circ$and ± 2 hours.

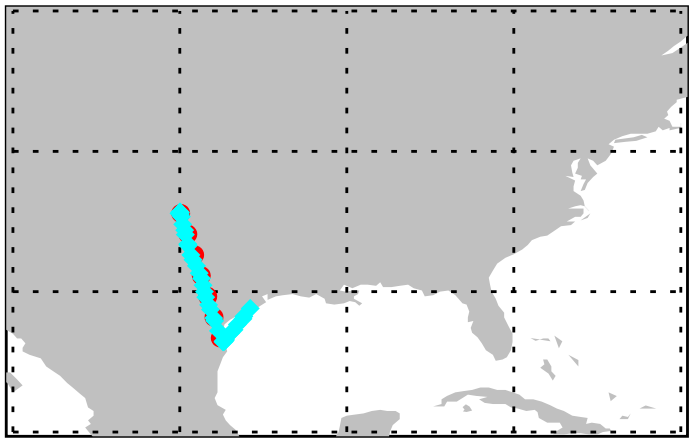
In-situ comparisons from balloon

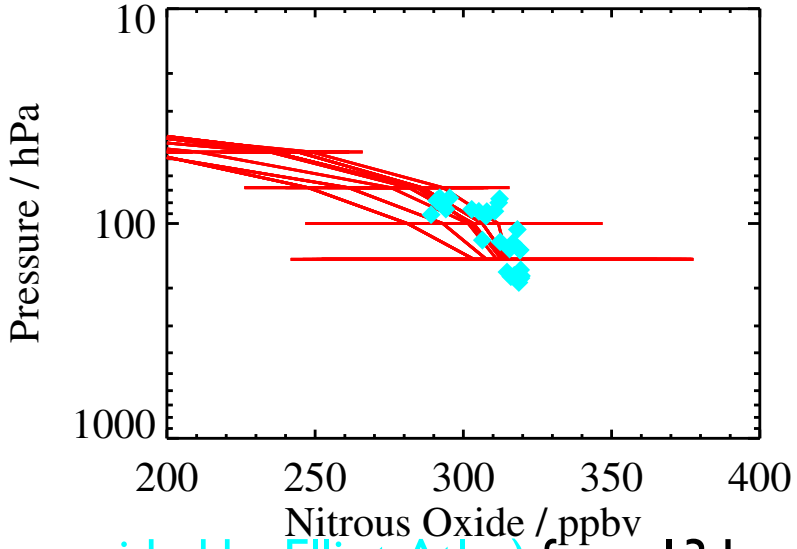


- This profile compares MLS to in-situ balloon data from Jim Elkins from last September.
- This comparison was shown during the March Aura Science team meeting.
- The grey region is the balloon observations.

- Red profile with error bars is closest MLS profile.
- Black line is balloon data appropriately interpolated to the MLS pressure grid.
- The agreement is excellent, well within the MLS error bars.
- Little more can be done with a single profile comparison such as this.

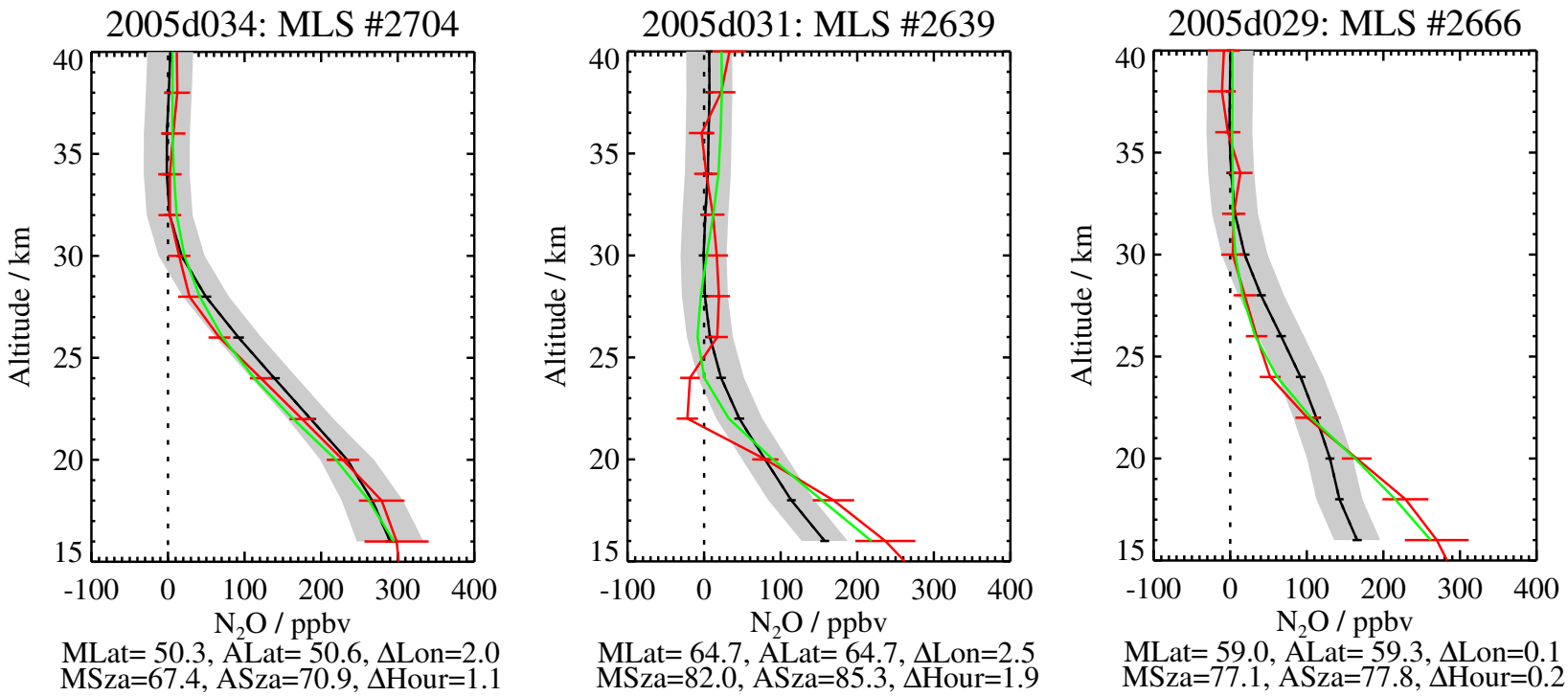
In-situ comparisons from the June AVE





- MLS (red) compared to WAS data (cyan, provided by Elliot Atlas) from 13 June 2005 AVE WB-57 flight.
- This WB-57 flight was planned to fly under the MLS track.
- There is little vertical overlap between the MLS and WB-57 N_2O data.
- We see excellent agreement for all the points, well within the MLS error bars.
- Other, geographically more distant comparisons are still excellent.
- Given what we've seen above, and the expected behavior of N_2O, we would pretty much expect this level of agreement, but it's nice to see it nevertheless.

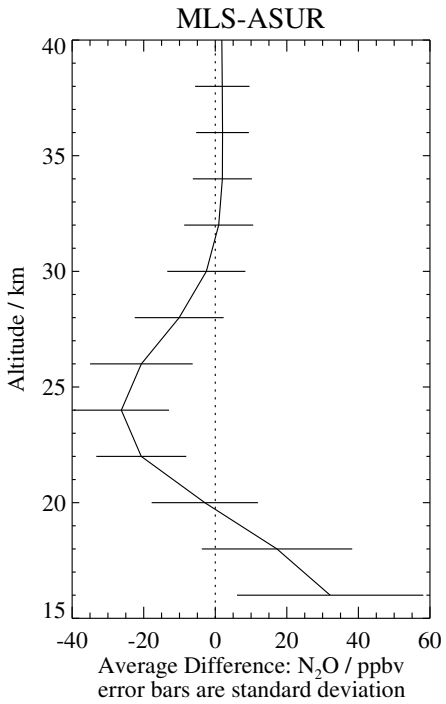
Representative comparisons with PAVE/ASUR

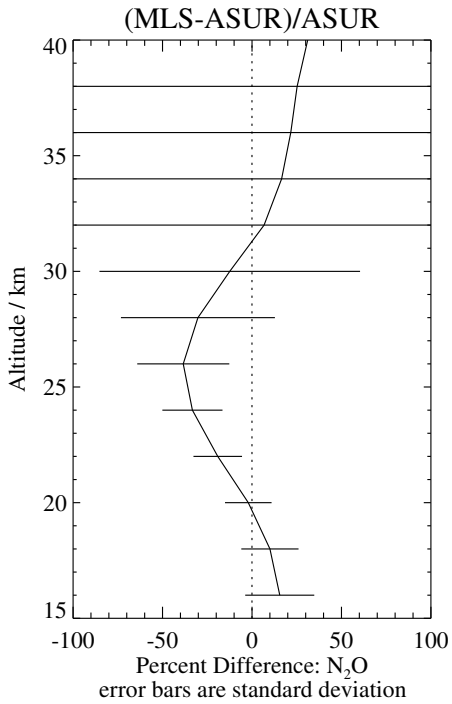


- Black line is ASUR with estimated precision (error bars) and accuracy (shading).
- Red line is MLS (interpolated to the ASUR heights via MLS geopotential height).
- Green line is **MLS** data multiplied by the **ASUR** averaging kernels.
  - ⇨ This is the unfamiliar way round, because the ASUR resolution is poorer than that of MLS.
- Left hand case shows excellent agreement.
- Middle case shows that factoring in the ASUR resolution significantly improves the comparison.
- Right hand case shows example of poorer agreement (but still within $\sim 2\sigma$).

Summary of PAVE/ASUR comparisons

- Plots to right summarize all 27 PAVE/ASUR coincidences.
- Some significant biases are evident.
- MLS is 10–20% higher than ASUR below 20 km.
- At 20–30 km, MLS is 20–40% lower than ASUR.
- Above that, agreement is within a few ppbv.

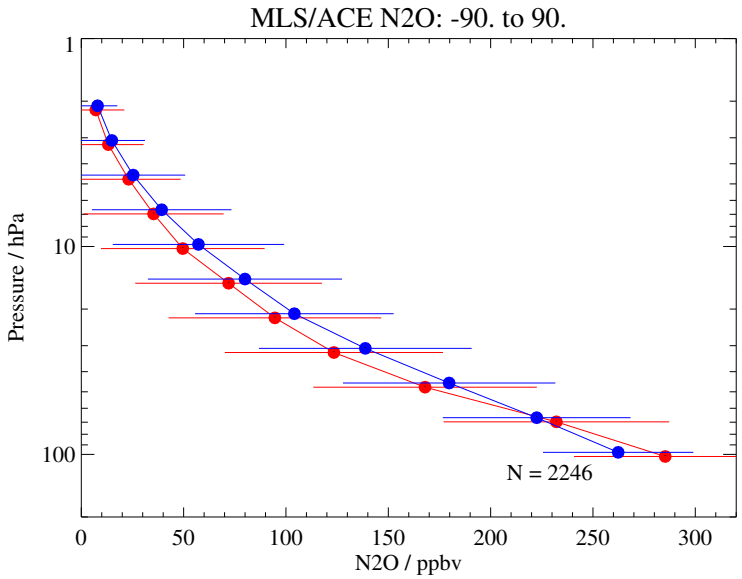


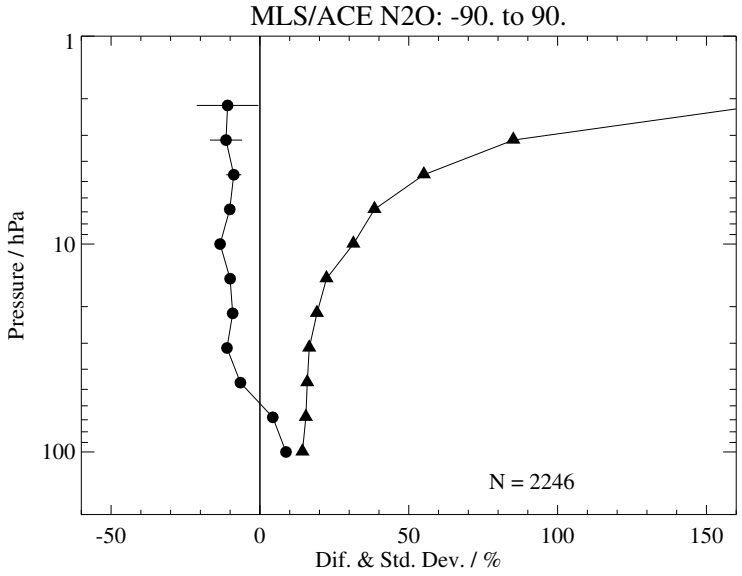


- The various manipulations (averaging kernels etc.) make computing the expected levels of agreement somewhat tricky.
- The disagreement below ~30 km is probably statistically significant.

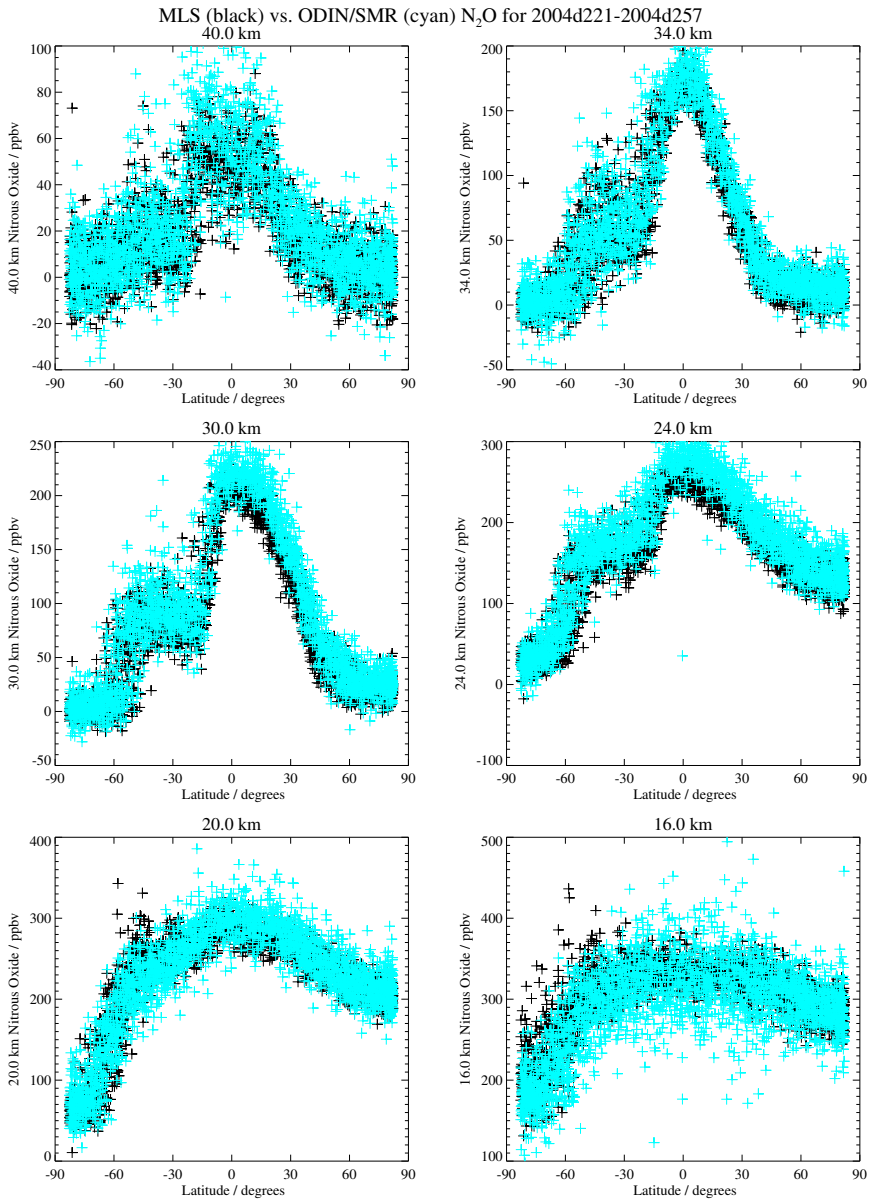
Comparisons with ACE

- Kaley Walker will be talking about MLS/ACE N_2O comparisons in more detail.
- The top plot shows global mean MLS (red) and ACE (blue) comparisons.
  - ⇨ Error bars are for individual profiles.
- The bottom plot shows the percent absolute differences (dots) and rms differences (triangles).
  - ⇨ Here, error bars are errors in the mean.
- MLS appears consistently about 10% lower than ACE. The scatter between the two is about 15% in the lower stratosphere, increasing higher up (mainly due to decreasing N_2O values).



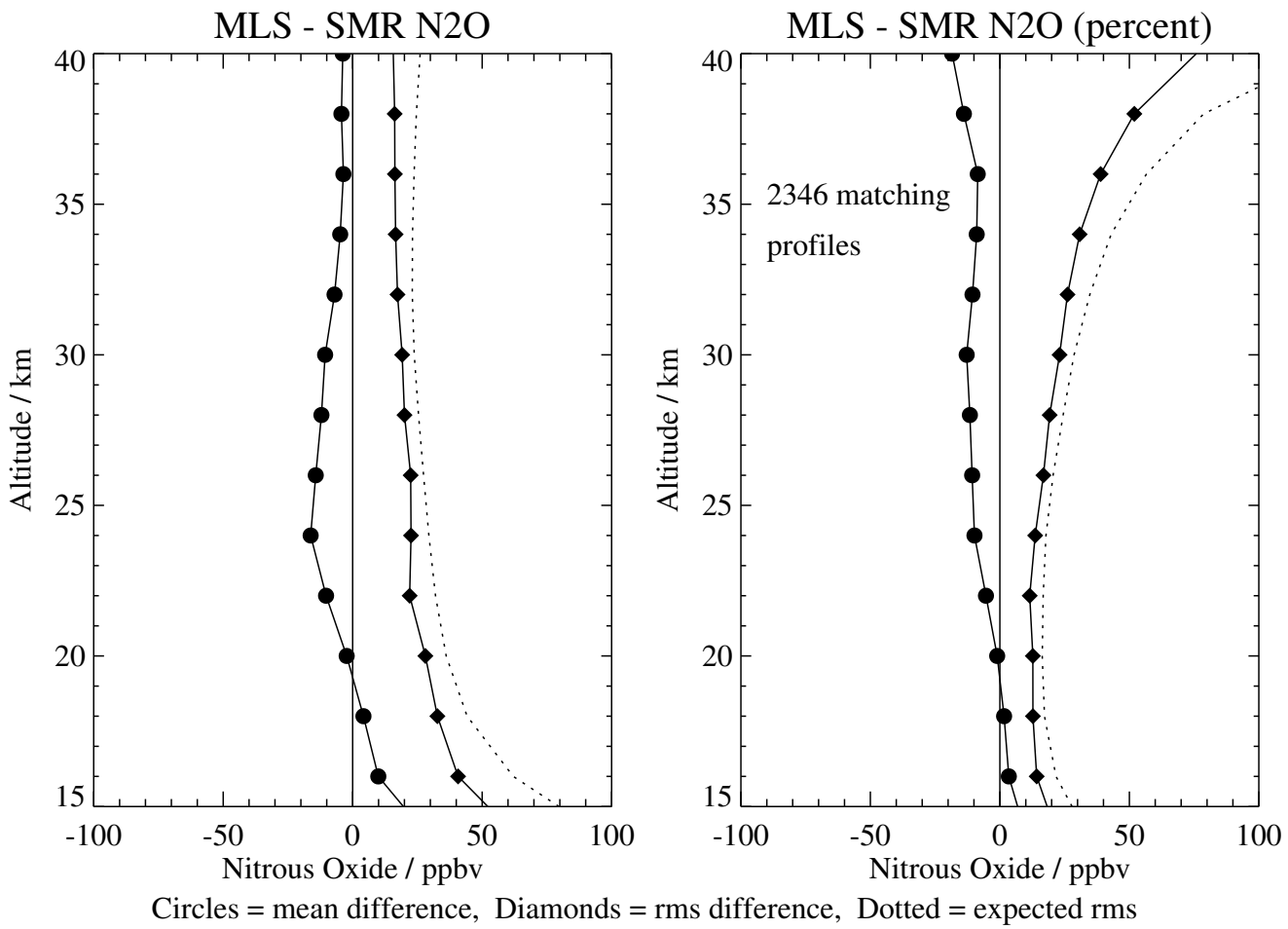


Comparisons with ODIN/SMR — scatter plots



- We have obtained ODIN/SMR data (Chalmers version '2') for the period 8th August to 13th December 2004.
- Here we see MLS (black) and ODIN/SMR (cyan) scattered vs. latitude for coincident profiles.
- The agreement is generally good, though SMR appears noisy at 14 km.
- There are hints that SMR is generally a little higher than MLS.

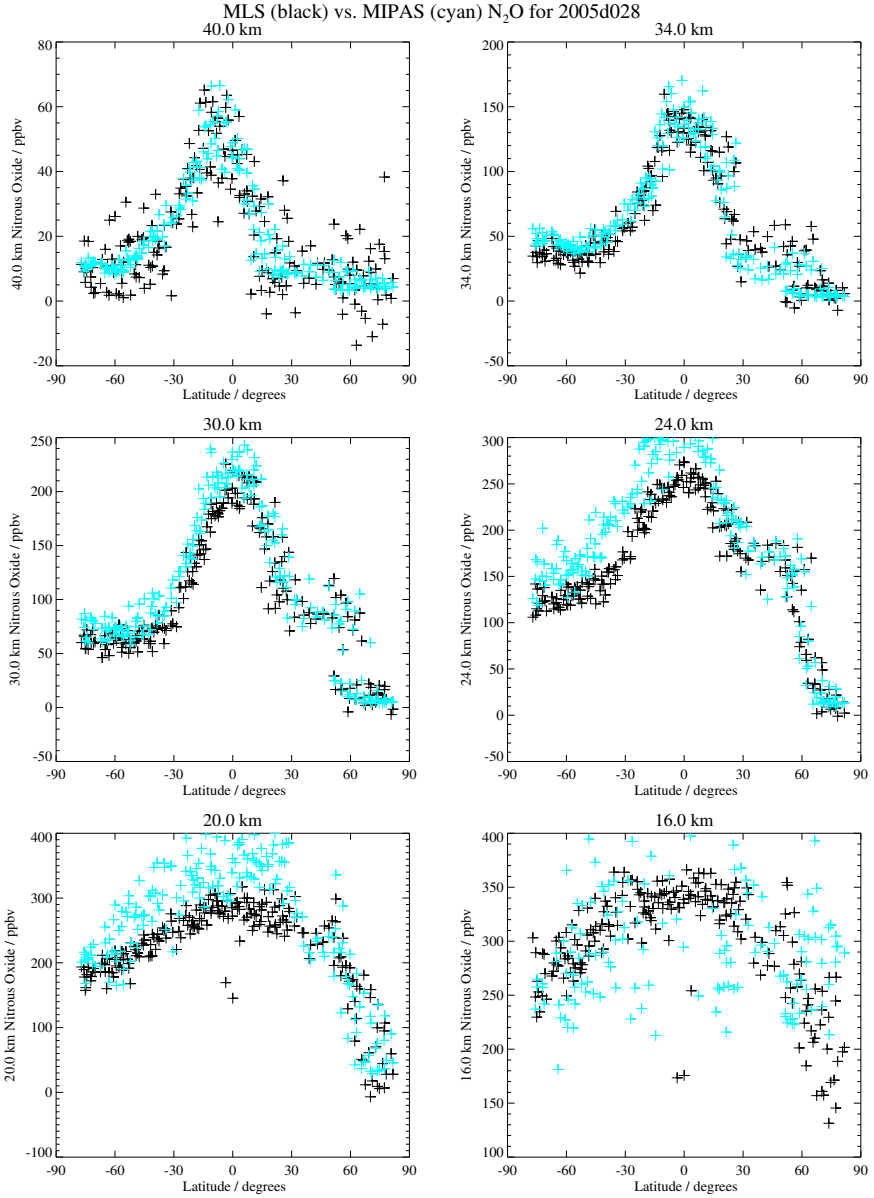
Comparisons with ODIN/SMR — summary



- Circles show mean MLS–SMR difference.
- Diamonds show rms agreement.
- Dotted line is the expected rms from reported uncertainties.

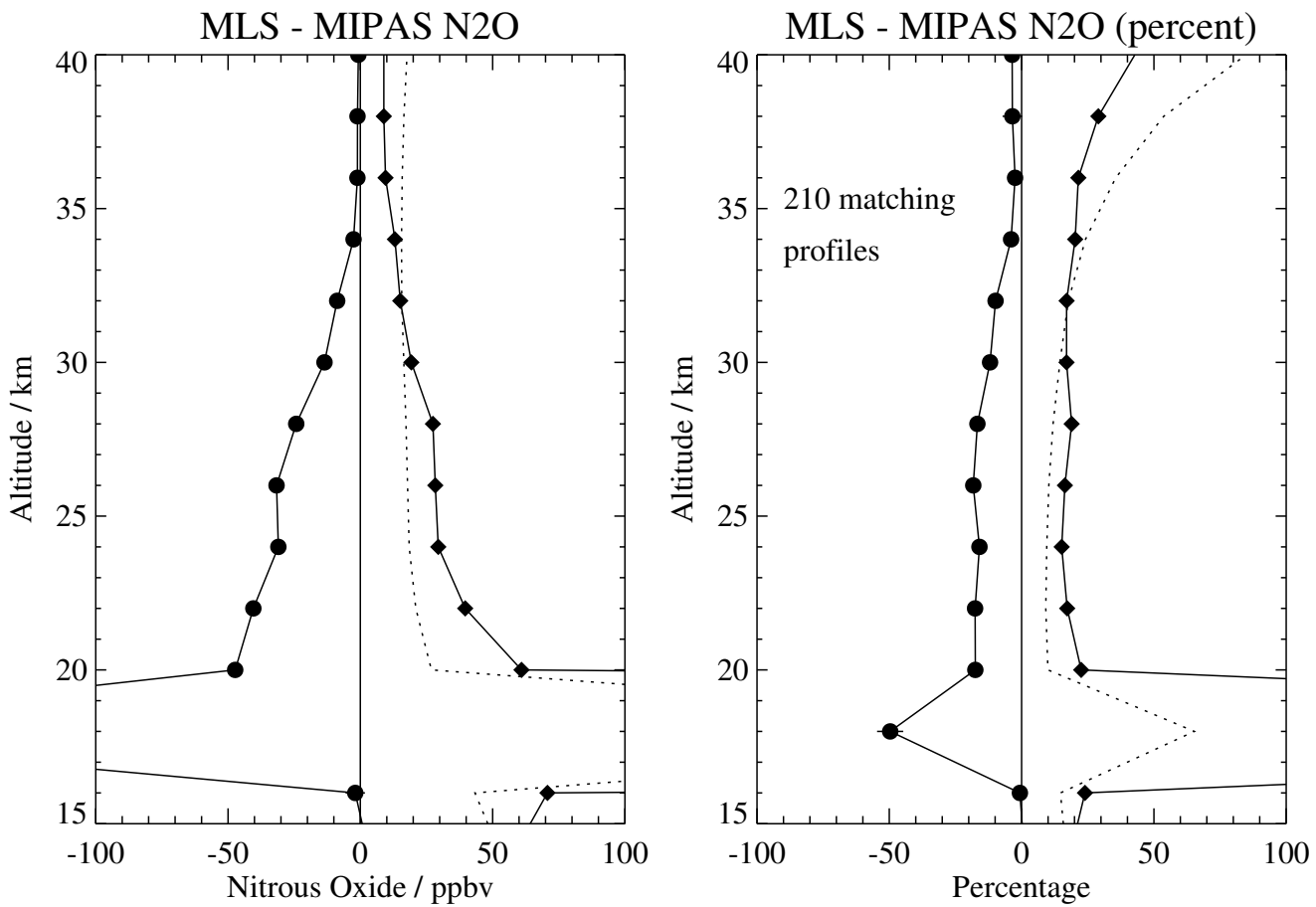
- Mean is over 2346 comparisons. Biases are clearly statistically significant.
- MLS and SMR agree to within 10–15% over most of the stratosphere, with MLS generally reporting lower abundances.

Comparisons with MIPAS — scatter plots



- We have obtained MIPAS data for 28th January 2005 (three orbits).
- These are "Preliminary Oxford Retrievals" from Claire Waymark at Oxford University.
- As for ODIN, we see MLS (black) and MIPAS (cyan) scattered vs. latitude for coincident profiles.
- MIPAS N_2O seems higher than MLS in the lower stratosphere, particularly in the tropics.

Comparisons with MIPAS — summary



- Circles show mean MLS–MIPAS difference.
- Diamonds show rms agreement.
- Dotted line is the expected rms from reported uncertainties.

- Agreement with MIPAS is a little worse than with ODIN/SMR.
- MLS and MIPAS seem to differ by about 20%, with MLS reporting lower N_2O abundances.

Conclusions and future work

- Version 1.51 MLS N_2O observations seem very reasonable.
- A few anomalies, described in the quality document, should be borne in mind.
- Comparisons with in-situ observations show excellent agreement.
- Comparisons with ASUR show 20–40% disagreements.
- Comparisons with other satellite instruments are generally within 10–20%, with MLS generally lower than the other instruments.
- The 190 GHz 'diagnostic' N_2O product shows less bias in the mid- and upper stratosphere, but strong biases are clear in the lower stratosphere.
- Priorities for version 2 are:
  - ⇨ Refine spectroscopy information in the 640 GHz region (particularly the contaminating O_3 lines).
  - ⇨ Investigate other potential sources of bias.
  - ⇨ Fix poor convergence and non-convergent cases.